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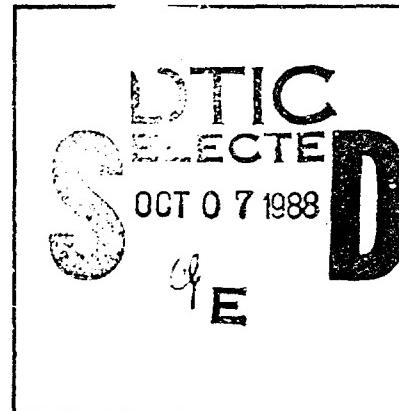
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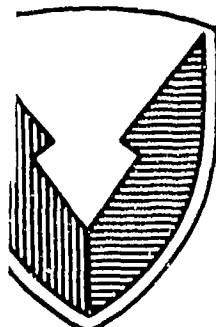
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Technical Report

No. 13377

CONTINUED SIMULATION TESTING OF THE MK-9 MOL

MACHINE GUN SUPPORT KIT

JULY 1988

Arthur L. Helinski
U.S. Army Tank-Automotive Command
ATTN: AMSTA-RYA
By Warren, MI 48397-5000

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A prototype MK19 MOD3 Grenade Machine Gun Support Kit was designed and developed for the M54A2 5-ton truck. This report details a unique test that was implemented in the U.S. Army Tank-Automotive Command's (TACOM) Physical Simulation Laboratory to reproduce the dynamic forces the machine gun kit normally encounters as the truck travels across terrain. The truck was simulated over selected terrains which produced the state variables of the fixture. Real-time simulation testing of prototype vehicle systems is a proven method of reducing costly development and field testing.

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PREFACE

This report covers the continued testing of the machine gun kit which was previously tested on an M342A2 (w/w) 2½-ton truck by the same method and should be considered a supplement to "Simulation Test of the MK19 MOD3 Grenade Machine Gun Support Kit."¹ Any questions regarding the adequacy of the machine gun mount design are to be referred to the U.S. Army Tank-Automotive Command, ATTN: Light and Medium Truck Branch (Doug Petron), Warren, MI 48397-5000.

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1.0. INTRODUCTION

This report, prepared by the Analytical and Simulation Branch of the Tank-Automotive Technology Directorate, at the U.S. Army Tank-Automotive Command (TACOM), details a test used to reproduce dynamic forces that a machine gun kit normally encounters as an M54A2 (5-ton) truck travels over cross-country terrain. The machine gun kit, a new version developed by AM General to support the MK19 MOD3 machine gun, was tested in TACOM's Physical Simulation Laboratory.

In this report the M809-series 5-ton truck is referred to simply as the 5-ton truck, while the M939-series 5-ton truck is referred to as the M939. The M342A2 will be referred to as the $2\frac{1}{2}$ -ton truck.

2.0. OBJECTIVES

The primary objective of the test was to evaluate the structural integrity of the truck cab and machine gun mount subject to dynamic forces induced when the vehicle traverses typical cross-country terrain profiles. These controlled laboratory tests provide information regarding the durability of the design and can reveal potential problem areas.

An additional objective was to compare the results of the controlled lab tests to results from field data.

3.0. CONCLUSIONS

A cab failure occurred during the laboratory simulations which required a design modification to the cab structure. The failure consisted of cracks around the upper gussets and on the rear channel reinforcements. A design modification which was implemented after the failure was identified consisted of adding a reinforcement plate to this area. A light-gauge sheet metal plate was riveted to the entire rear cab structure behind the seats.

In addition, weights representing two of the three ammunition boxes were removed to eliminate some weight from the gun ring, reducing the load causing the failure. The remaining mission profile was then completed without any additional failure.

Any effective repair on the cab will have a very good chance of surviving any future field testing. Without simulation testing, the need for a repair may not have been noticed until safety certification testing.

Rivets were applied to the 5-ton truck at the end of gussets at the start of the testing. These rivets were applied to prevent weld cracking between the gussets and door pillars and were initiated from the results

of the 2½-ton truck test. Although the rivets held in place during the testing a new failure did surface after 526 miles of simulation which required further design modification to the truck cab structure.

During the laboratory simulation testing, a similar test was being conducted at Chrysler Proving Grounds (CPG) by AM General, the contractor for the 5-ton and 2½-ton vehicles. The testing consisted of determining the structural integrity of the machine gun mount installed on an M939 truck traveling over the cross-country terrain profiles of Chalma Road, one of the roads at CPG.

The analysis conducted on the data from CPG has indicated that the testing there demonstrated about the same levels of severity as the laboratory testing. A direct comparison cannot be made because the terrain profiles simulated for the testing and the CPG profiles are different. However, it can be concluded that the rms accelerations at the wheel spindles and driver's seat indicate that the field data and laboratory data have nearly the same levels of severity. The absorbed power, which is a means of determining ride roughness, is also comparable between the field data and laboratory testing.

In addition, the failures reported from the M939 at CPG were similar in nature to the cab failures recorded during the 2½-ton and 5-ton truck laboratory simulation testing. It can be concluded that laboratory testing provides a realistic dynamic environment.

4.0. RECOMMENDATIONS

It was recommended that tests representing a complete mission profile be performed after design modification was introduced so that durability could be assured. Due to lack of funds only a portion of the mission profile was completed after the modification to the truck cab.

It is recommended that the effective repair made on the cab be considered a design modification for the use of the machine gun mount support kit. Further testing such as the safety certification test must be made to determine the durability of this new design. At this time it is recommended that two ammunition boxes not be carried on the machine gun support kit until further testing can be done. The weights representing these ammunition boxes were removed after the failure occurred during the tests. Permission was granted by the U.S. Armament, Munitions and Chemical Command (AMCCOM) to waive operational requirements to allow us to remove these weights from the vehicle.

5.0. DISCUSSION

5.1. General

The testing of the machine gun mount of the 5-ton truck (M54A2) is a continuation of the testing conducted on the 2½-ton truck (M342A2). The

design modifications made during the testing of the 2½-ton truck were incorporated into the 5-ton truck. A similar mission profile scenario was used for both truck tests.

The test plans for these truck projects were aimed at testing the structural integrity of the installed machine gun support kit. Testing was conducted by means of physical laboratory simulation (shaker tests) which duplicates the forces encountered as the vehicle traverses various cross-country terrain profiles. It was decided that if any failures occurred during testing, design modifications could be made to the machine gun kit and/or truck cab and testing could be resumed.

The new machine gun kit is used on various trucks. It consists of a machine gun ring fixture which is mounted to the back and front of the truck cab. The machine gun mount tested on the 2½-ton truck was a slightly modified version of the current models in production. The changes affected the mass, hardness and thickness of the support legs which are fastened to the truck cab.

The design of the machine gun mount was further modified for the preparation of the 5-ton truck tests. These changes were directly influenced by the results of the testing conducted on the 2½-ton truck and primarily consisted of applying rivets to the ends of the gussets (cross brackets in the cab behind the seats). During the testing of the 2½-ton truck, weld cracks kept reappearing around the gussets even after rewelding repairs were made. Rivets were installed on each end of both gussets. It was believed that the use of rivets would reduce the stress on the welds, thus eliminating further cracking. The final inspection of the cab, after a complete mission profile, indicated that the rivets held in place although a small amount of slippage did occur. The 5-ton truck is considered to have the same cab structure as the 2½-ton truck. It was recommended by AM General that no action be taken in regard to the development of cab modifications until the 5-ton truck test was complete. It was decided that if these rivets prove to be effective, they will be recommended for incorporation into the final machine gun mount design.

Various forms of data were recorded by AM General from the physical laboratory simulation and field data from CPG during the testing of the machine gun mount kit. TACOM was asked to perform an accurate analysis of the data obtained by using a computer system capable of performing a statistical analysis of the acceleration levels encountered, and for the determination of the absorbed power at the driver's seat. The study would determine the levels of severity for both field data and physical simulation testing. TACOM had taken on this task by preparing a data acquisition computer program to conduct this analysis by sampling recorded data. Some of the results of the analysis are presented in this report.

5.2. Machine Gun Mount Design

As previously mentioned, the machine gun mount kit being tested is designed to support the MK19 MOD3 Grenade Machine Gun. The kit used during testing had been changed slightly from those currently in production.

Three failures were encountered during the 2½-ton truck simulation laboratory testing. One failure was located at the lower right corner of the dash panel. The other two failures were cracked welds on the right and left gussets, which are a part of the rear cab channel reinforcements. Four rivets (3/16-inch diameter) were installed on each end of both gussets. The final inspection of the cab during the 2½-ton truck test indicated that although the rivets appeared to remain in place, a small amount of slippage did occur between the gusset and the door pillar on the driver's side of the vehicle.

The 5-ton truck was tested with upgraded modifications which were developed on the basis of the results of the 2½-ton truck test. These modifications consist of using four (.25-inch diameter) rivets on each end of both gussets, the addition of a larger bolt and bracket-weldnut assembly located above the upper bolt at the dash panel flange. The failure at the dashboard on the 2½-ton truck was thought to be caused by a loose bolt which secures the support bracket for the front post assembly of the machine gun mount kit.

The support kit tested on the 2½-ton truck was a model P/N 12301284. A model P/N 11677311 was tested on the 5-ton truck. Testing on both trucks was conducted using an M66 gun ring and MK64 gun mount, weighted properly to represent an MK19 MOD3 Grenade Machine Gun with three 51.5-lb cans of ammunition. Simulated weights of two 175-lb truck occupants were also added.

5.3. Simulation Process

A computer-based model of the truck was created by means of the Dynamic Analysis and Design System (DADS) methodology. The analytical simulation was performed using selected terrain profiles to "excite" the vehicle. From the results of the simulations, time histories were recorded representing the motion for each wheel spindle. A detrending process was used to convert the analytical time histories into waveform data which are within the limits of the physical simulator's capabilities. The waveform data are then transferred to a digital computer system which interacts with the hydraulic controllers of the physical simulator. Waveform data were transformed to voltages representing command signals by means of digital to analog (d/a) conversion. The command signals provide control to hydraulic actuators which reproduce these motions on the actual vehicle. The simulation process is described in much more detail in "Simulation Test of the MK19 MOD3 Grenade Machine Gun Support Kit,"² where each step is detailed.

There has been some concern that the severity levels of the terrain simulations used for the laboratory testing were too mild. The 2½-ton truck tests consisted of running the vehicle over a 1,500-mile mission profile of simulated cross-country terrain while not exceeding an absorbed power level of 6 watts maximum. The 5-ton truck test used similar terrain simulations, however, the absorbed power 6-watt criterion was lifted on several runs so that harsher simulations would be used. In addition, the analytical modeling results showed that the 5-ton truck was a much harsher riding vehicle than the 2½-ton truck.

Table 5-1 shows a portion of the results which were measured during the testing. It should be mentioned that much more severe course/speed runs could have been run but were not included in the tests. The hydraulic actuator motion base simulator was capable of providing a much more severe ride, but there was some concern over the potential of mechanical breakdowns. The measured actuator position responses are included in Appendix B for each course/speed cycle used in the testing. Most of the terrain profiles recorded for analytical model inputs are two-dimensional. On the 2½-ton truck testing, a delay was made between the left and right signals to produce a pseudo three-dimensional simulation by contributing a roll motion to the vehicle. The 5-ton truck test presented in this report was improved by simulating the left and right shift in the terrain data itself. Thus the DADS methodology provided a shifted terrain profile between the left and right side rather than applying the shift to the signals driving the left and right actuators. The results produced a more realistic roll motion in the laboratory simulation testing.

5.4. Field Data Analysis

During the testing of the 5-ton truck in the physical simulation laboratory, a similar test was conducted in the field at CPG with an M939 truck. The field testing was performed to determine the structural integrity with the machine gun support kit installed. Various acceleration data were recorded by AM General during the testing.

A joint effort was made between AM General and TACOM to conduct an analysis on the recorded field data to determine their level of severity. The data was recorded in analog signal form on tape which was played to the Computer Automated Measurement and Control (CAMAC) system for sampling by means of analog-to-digital (a/d) converters. Anti-aliasing filters were used during the sampling process to eliminate the high-frequency noise often present in accelerometer data. The data were then analyzed in the same manner as the data recorded from the laboratory testing. Table 5-2 shows the results of the analysis.

5.5. Results of the Simulation Testing

The analysis conducted on the data measured from CPG has indicated that the testing there demonstrated about the same levels of severity as the laboratory testing. The rms accelerations at the wheel spindles and

Table 5-1. Data Measured by TACOM--Physical Laboratory Simulation,
5-Ton Truck (M54A2) Testing

Course	Speed (mph)	Left	Front (Gs)	Vertical Acceleration			Driver's Seat* (Gs)	Driver's Absorb Power (Watts)		
				MIN	MAX	RMS		MIN	MAX	RMS
								VERT	F/A	S/S
CHV1	10	-1.6	1.9	.38	-.75	.81	.22	7.8	.45	.24
CHV6	30	-2.5	3.1	.38	-.64	1.1	.18	3.8	.27	.10
APG9	8	-2.2	2.1	.34	-.76	.70	.21	6.7	.62	1.35
APG11	5	-10.	4.7	.39	-.79	3.1	.15	2.7	.58	1.08
APG12	5	-1.3	1.2	.14	-.48	.32	.04	.91	.18	.47
APG37	20	-1.7	1.7	.48	-.59	.69	.14	1.9	.97	.70
Ft Knox	8	-3.9	2.7	.47	-.79	1.3	.20	5.9	1.1	1.2
Ft Knox	9	-4.1	4.8	.65	-.99	1.2	.34	11.8	1.2	1.3

KEY

VERT-Verticle
F/A-Fore and Aft
S/S-Side to side
MIN-Minimum
MAX-Maximum
RMS-Root mean square

*Driver's seat measurements made from
top of driver's seat.

Table 5-2. Data Measured by AM General--M939 Chrysler Proving Grounds,
Chelsea, MI, Chalma Road

Chalma Road Portion	Speed (mph)	Vertical Acceleration			Driver's Seat [*] (Gs)			Driver's Absorb Power (Watts)					
		Right Front (Gs)	Spindle	Driver's Seat [*] (Gs)	MIN	MAX	RMS	MIN	MAX	RMS	VERT	F/A	S/S
Pot Holes	5	-1.2	1.7	.24	-.73	1.15	.2	3.84	1.5	1.02			
Pot Holes	10	-3.1	3.4	.57	-.88	1.18	.28	8.25	1.8	.30			
Pot Holes	15	-4.2	4.9	1.1	-.90	1.31	.29	8.63	1.3	1.1			
Wash Board	5	-.71	1.2	.22	-.57	1.76	.29	5.71	1.4	1.1			
Wash Board	10	-2.2	2.8	.52	-1.0	1.2	.32	11.0	1.5	1.4			
Chuck Holes	15	-4.9	3.9	.51	-.67	.97	.19	4.2	.7	.6			
Straight Ditches	15	-5.0	4.9	.72	-1.2	1.4	.37	13.2	.5	2.8			

KEY

VERT-Verticle
F/A-Fore and Aft
S/S-Side to side
MIN-Minimum
MAX-Maximum
RMS-Root mean square

*Driver's seat measurements made from
cab floor below the seat.

driver's seat indicate that the field data and laboratory data had nearly the same severity. The laboratory test results could not be used for the validation of DADS because the CPG terrain profiles are considerably different from the profiles implemented in the laboratory. (It should be mentioned that other forms of analytical model validation studies are being conducted by TACOM for other vehicles at this time.)

A study was also made on validation of physical simulation performance used for this test and is presented in "Deriving an Empirical Model of an Electrohydraulic Actuator System by Frequency Response Data."³

A failure occurred after 526 miles of terrain simulation. The failure consisted of cracks around the upper gussets and on the rear channel reinforcements. A new reinforcement channel was added. This modification consisted of a light-gauge sheet metal plate riveted to the entire rear cab fixture behind the seats. The weights that represent two of the three ammunition boxes were removed and testing was resumed. The mile coverage up to the failure and the completed miles are given in the Appendix A. It was recommended that a complete mission profile be tested after the repair but due to funding only the mile coverage of the initial mission profile was completed.

LIST OF REFERENCES

- 1 Helinski, A.L., "Simulation Test of the MK19 MOD3 Grenade Machine Gun Support Kit," RDE Center Technical Report No. 13297, U.S. Army Tank-Automotive Command, Warren, MI (October, 1987)
- 2 Helinski, A.L., "Simulation Test of the MK19 MOD3 Grenade Machine Gun Support Kit," RDE Center Technical Report No. 13297, U.S. Army Tank-Automotive Command, Warren, MI (October, 1987)
- 3 Helinski, A.L., "Deriving an Empirical Model of an Electrohydraulic Actuator System by Frequency Response Data," RDE Center Technical Report No. 13368, U.S. Army Tank-Automotive Command, Warren, MI (1988)

APPENDIX A
MILE COVERAGE

FAILURE 1
MILE COVERAGE

OFF ROAD	154
TRAILS	169
SECONDARY ROADS	203
TOTAL SUM	526

Failure consisted of cracks around the upper gussets and on rear channel reinforcements. A reinforcement plate was installed consisting of light gage sheet metal riveted to the rear cab structure behind the seats. Weights representing two ammunition boxes were removed at this time to reduce some weight in the gun ring area.

FINAL MILE COVERAGE
COMPLETE MISSION PROFILE

OFF ROADS 250

TRAILS 260

SECONDARY RDS. 753

TOTAL SUM 1263

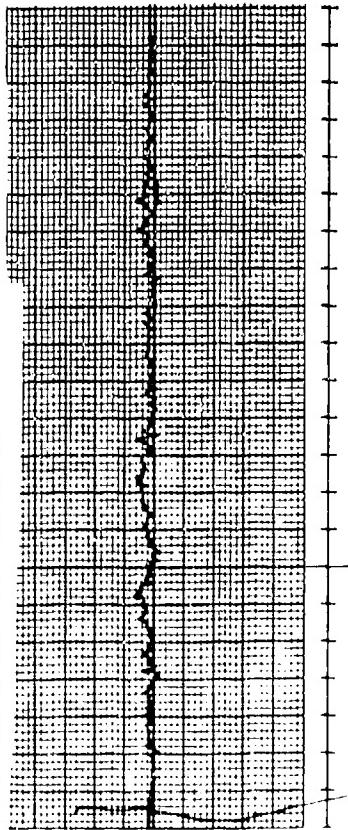
At this point funds to support the tests ran out, hence, plans for further testing had to be abandoned.

APPENDIX B
MEASURED ACTUATOR POSITION RESPONSE

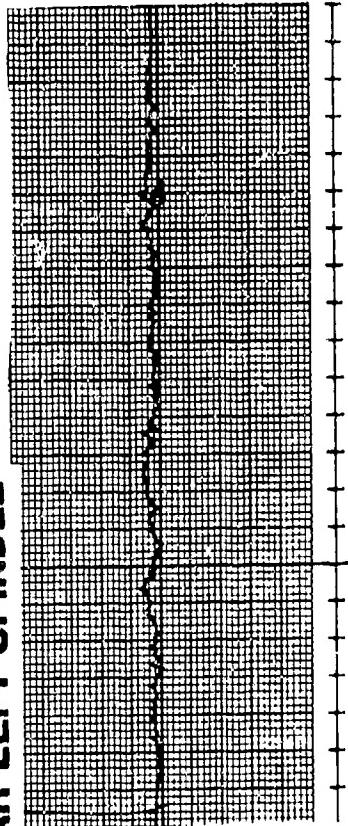
MEASURED ACTUATOR POSITION RESPONSE

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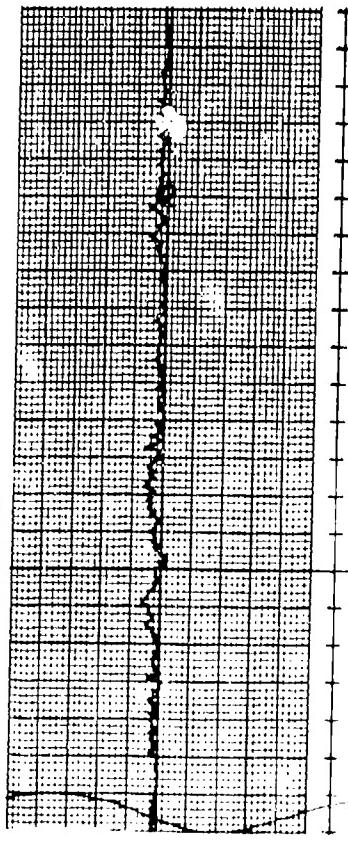
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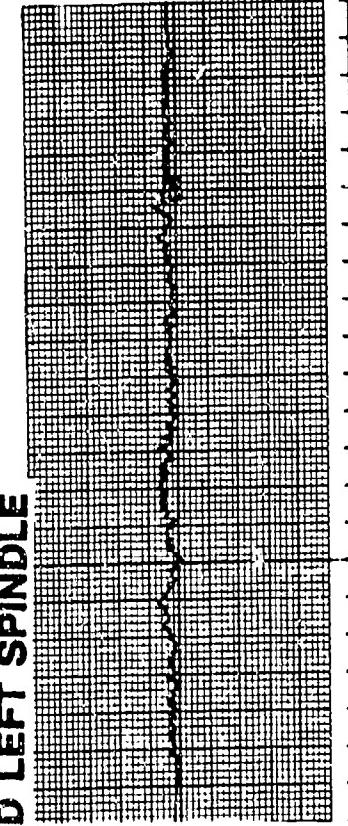
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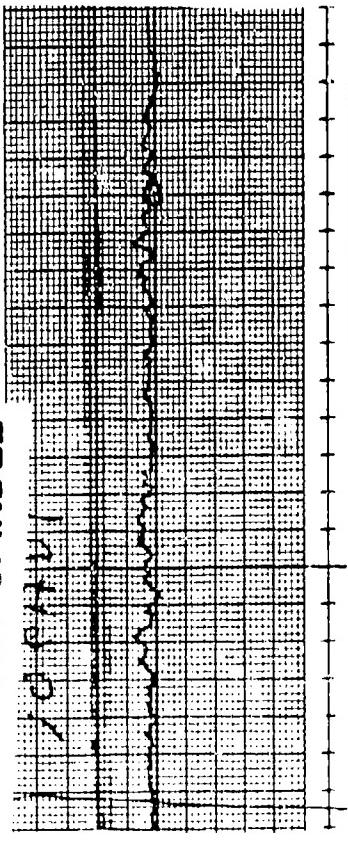
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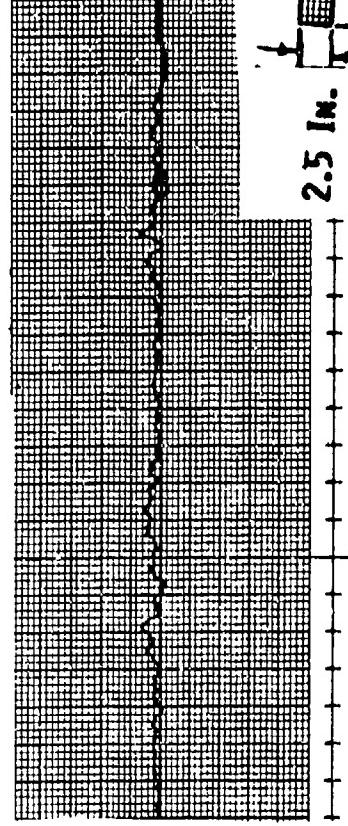
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FRONT RIGHT SPINDLE



FRONT LEFT SPINDLE

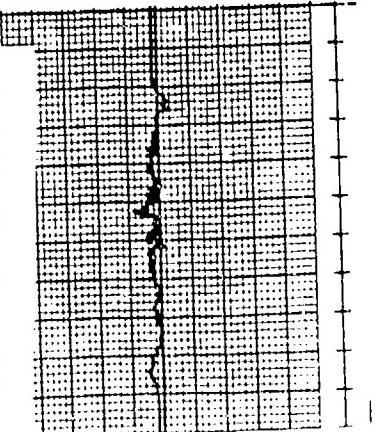


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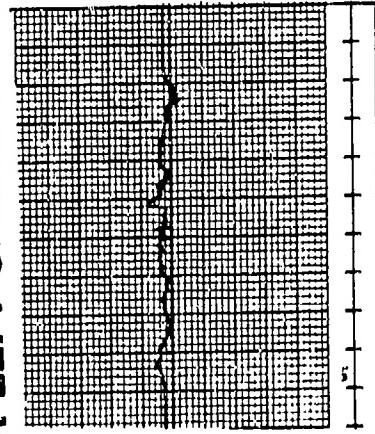
MEASURED ACTUATOR POSITION RESPONSE

CHv6 30 MPH

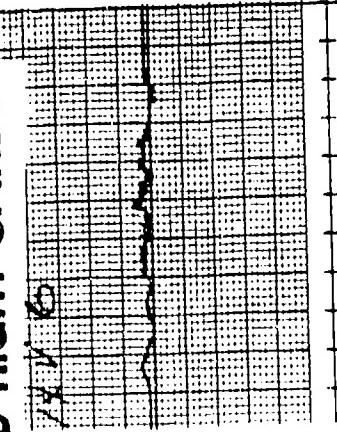
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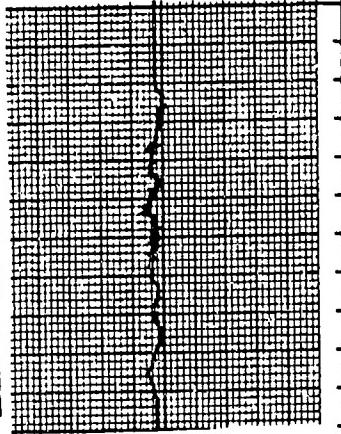
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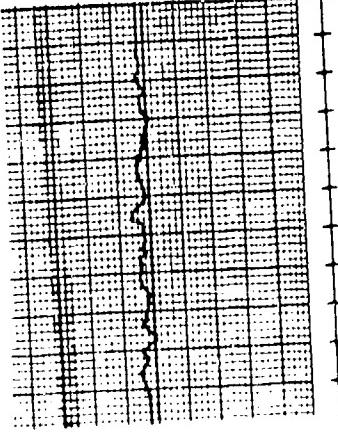
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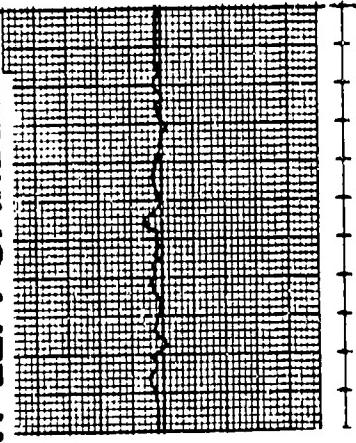
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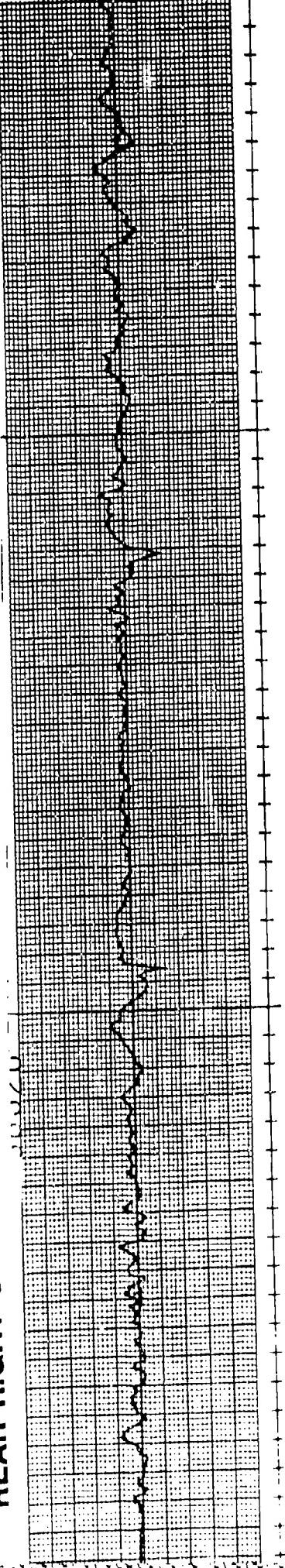


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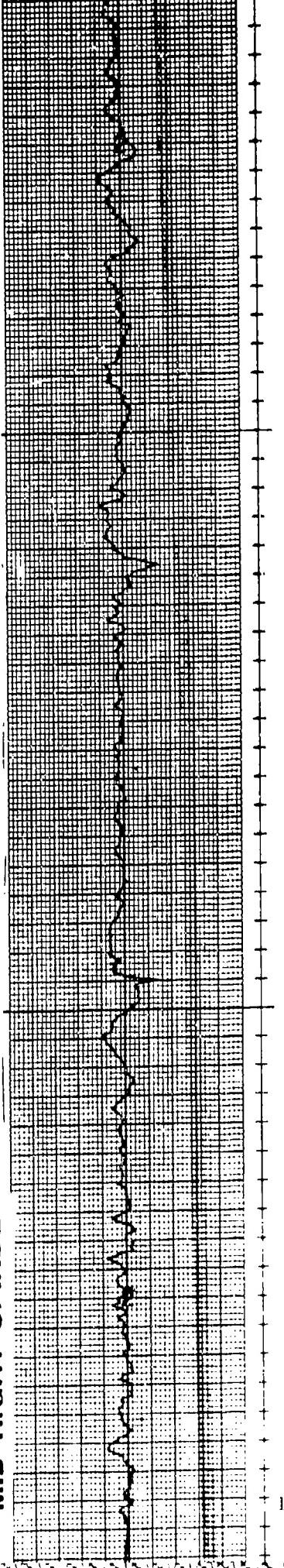
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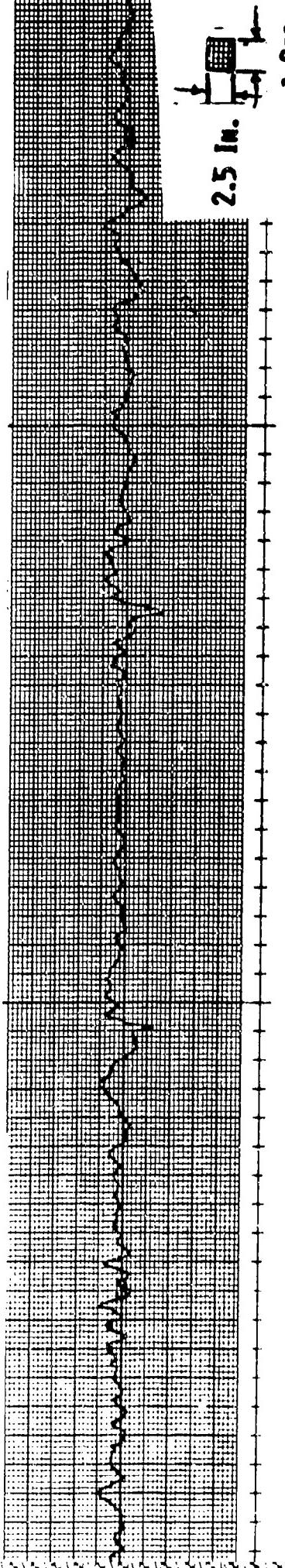
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MID RIGHT SPINDLE



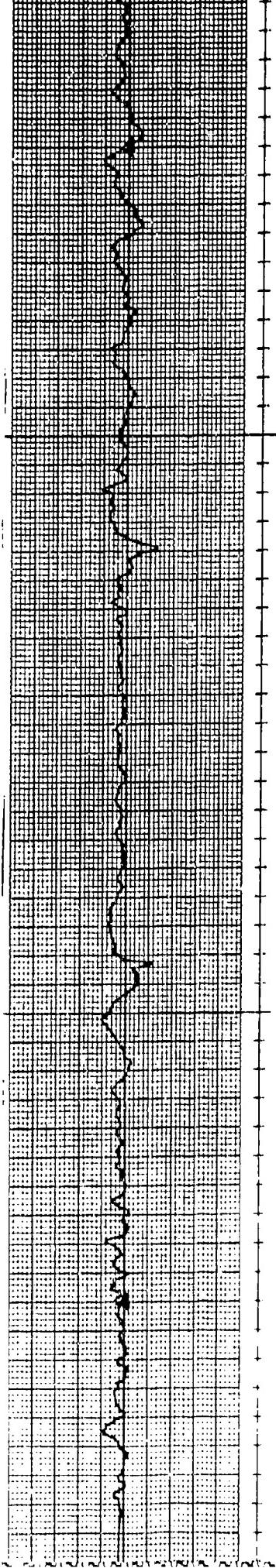
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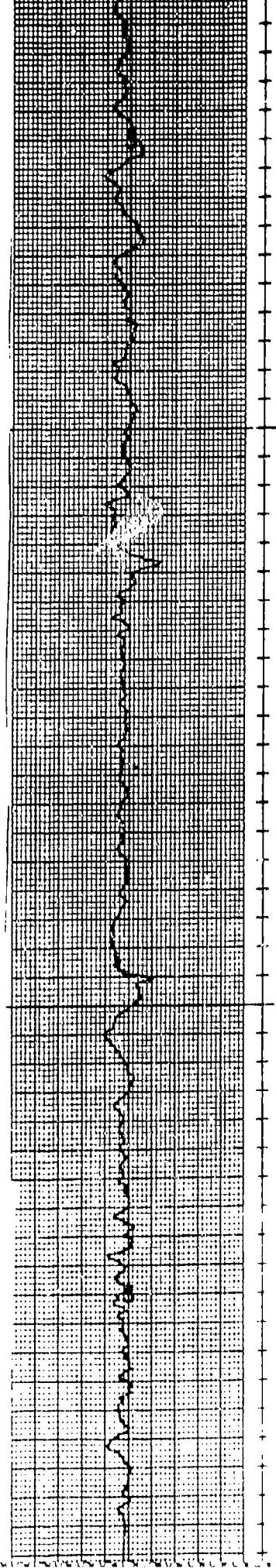
MEASURED ACTUATOR POSITION RESPONSE

APG11 5 MPH

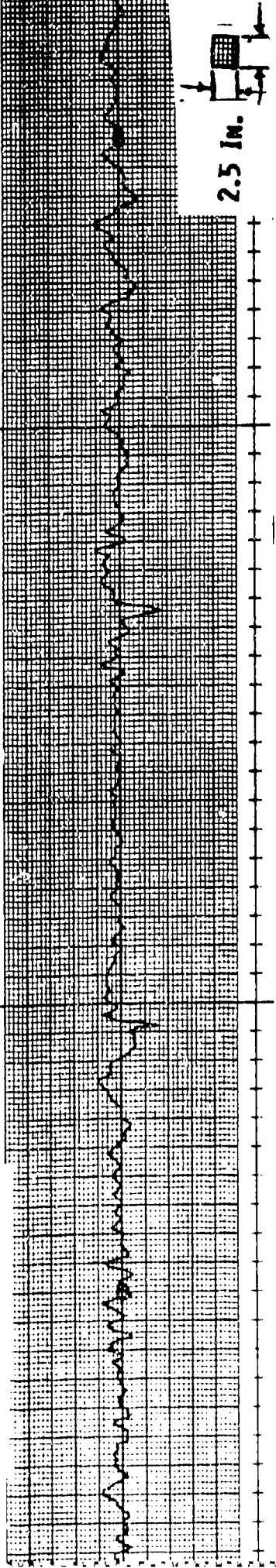
REAR LEFT SPINDLE



MID LEFT SPINDLE



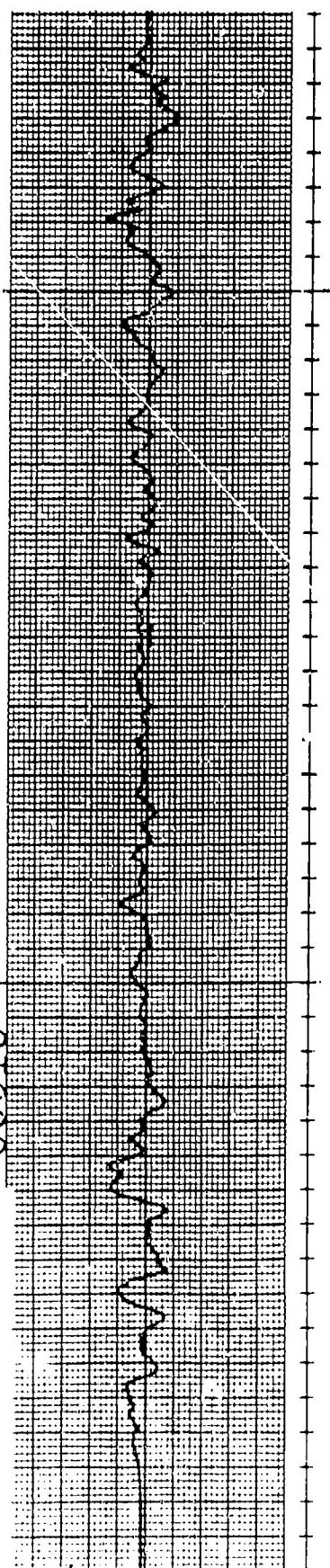
REAR LEFT SPINDLE



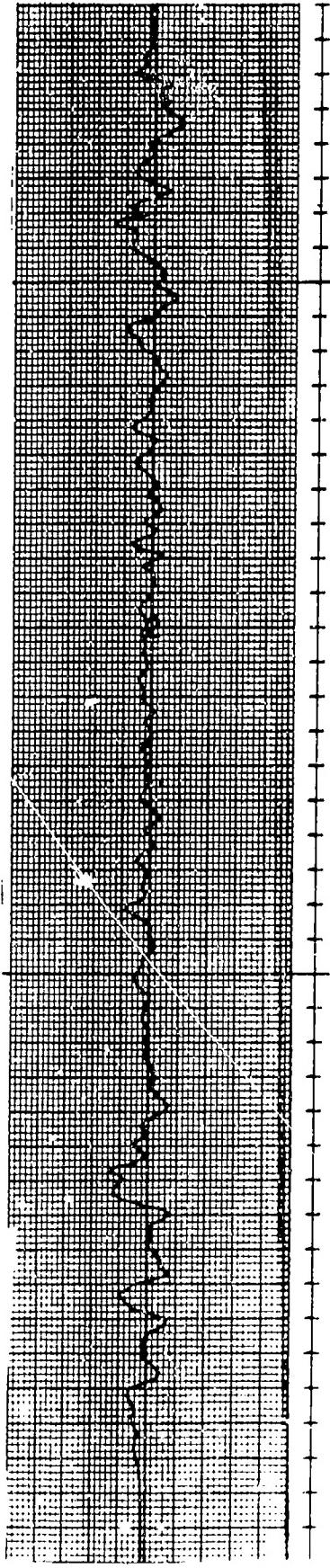
MEASURED ACTUATOR POSITION RESPONSE

APG12 5 MPH

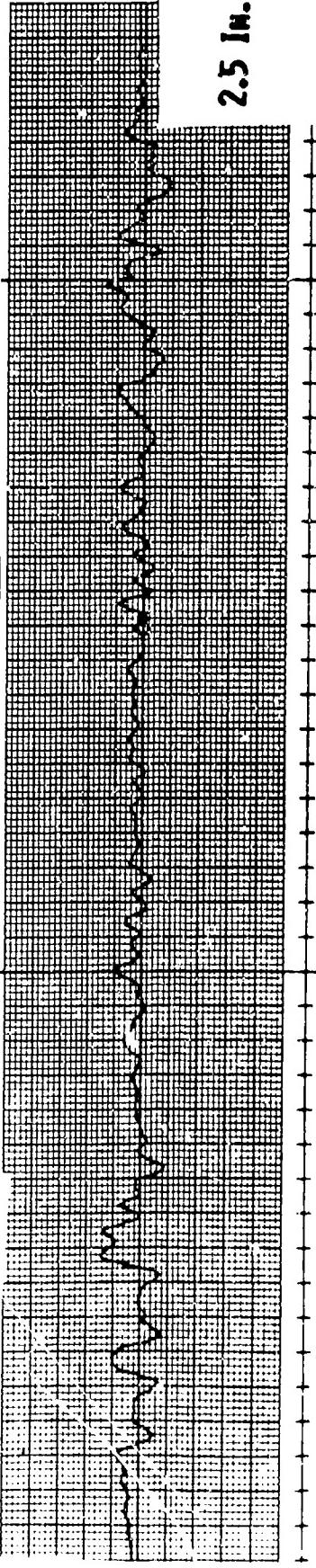
REAR RIGHT SPINDLE



MID RIGHT SPINDLE



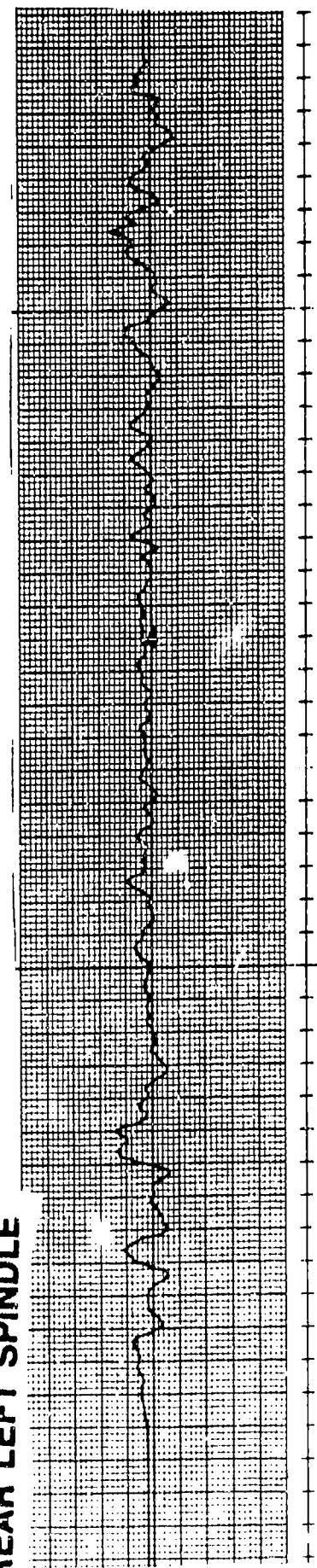
FRONT RIGHT SPINDLE



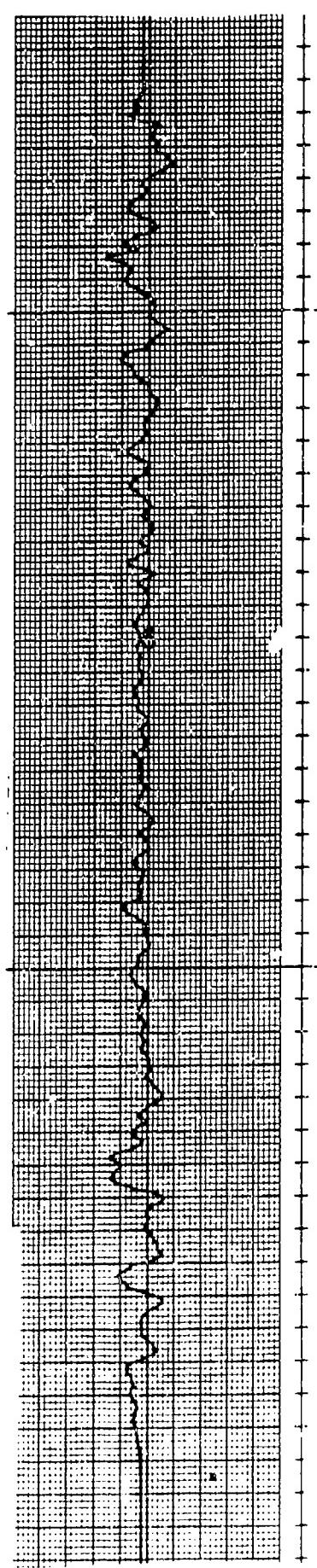
MEASURED ACTUATOR POSITION RESPONSE

APG12 5 MPH

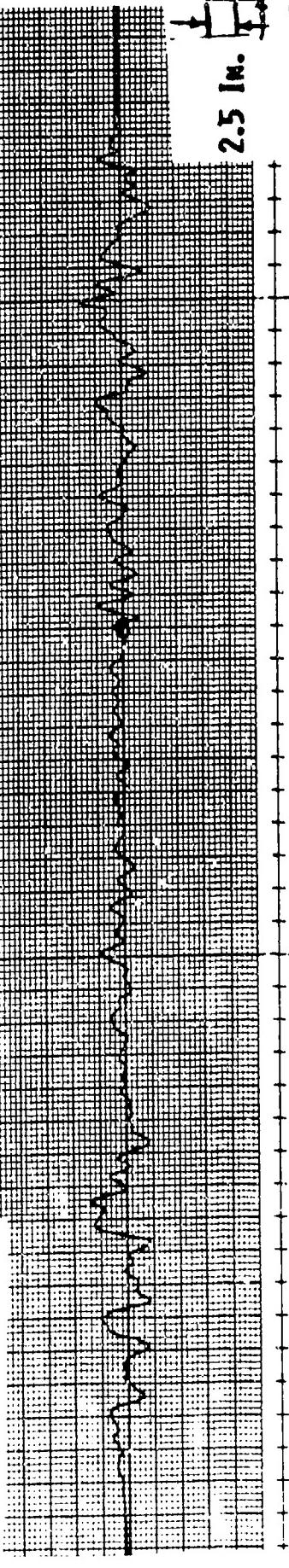
REAR LEFT SPINDLE



MID LEFT SPINDLE



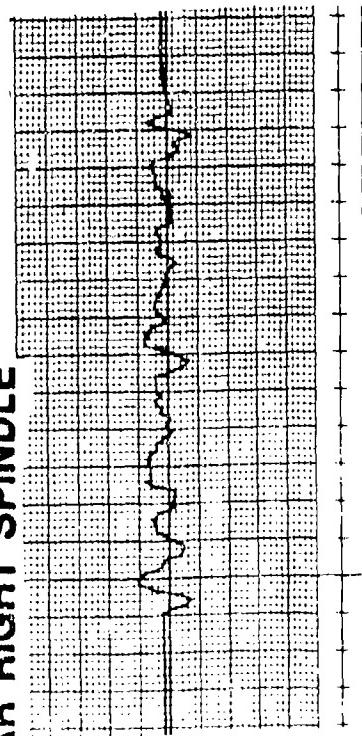
REAR LEFT SPINDLE



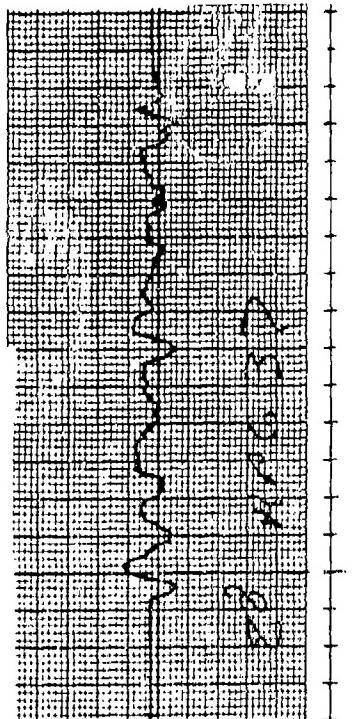
MEASURED ACTUATOR POSITION RESPONSE

APG37 20 MPH

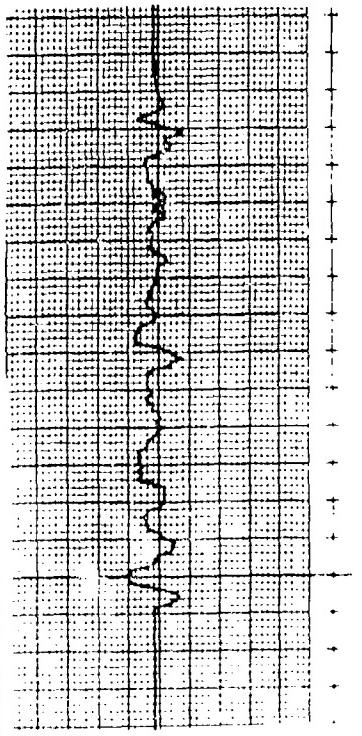
REAR RIGHT SPINDLE



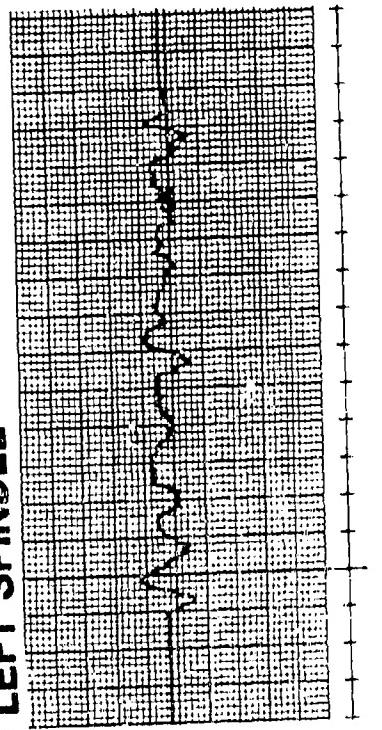
REAR LEFT SPINDLE



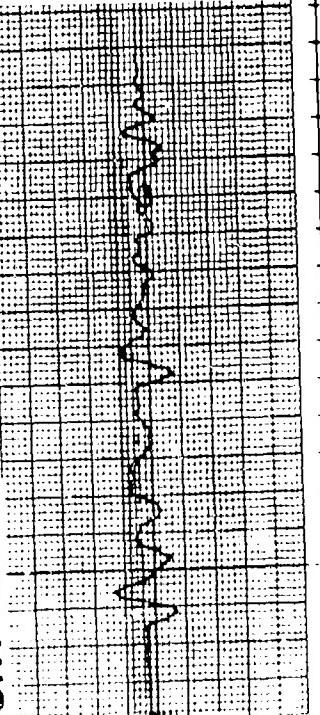
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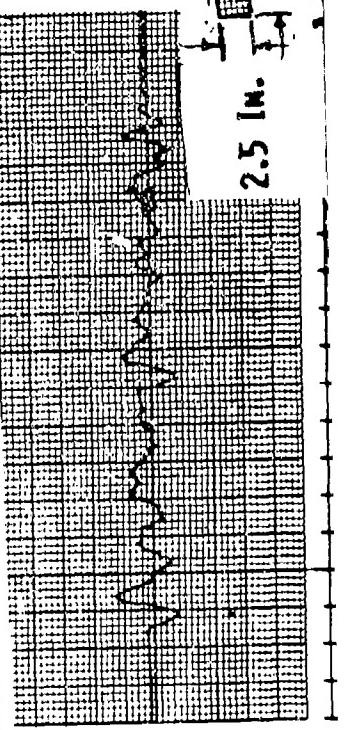
MID LEFT SPINDLE



FRONT RIGHT SPINDLE



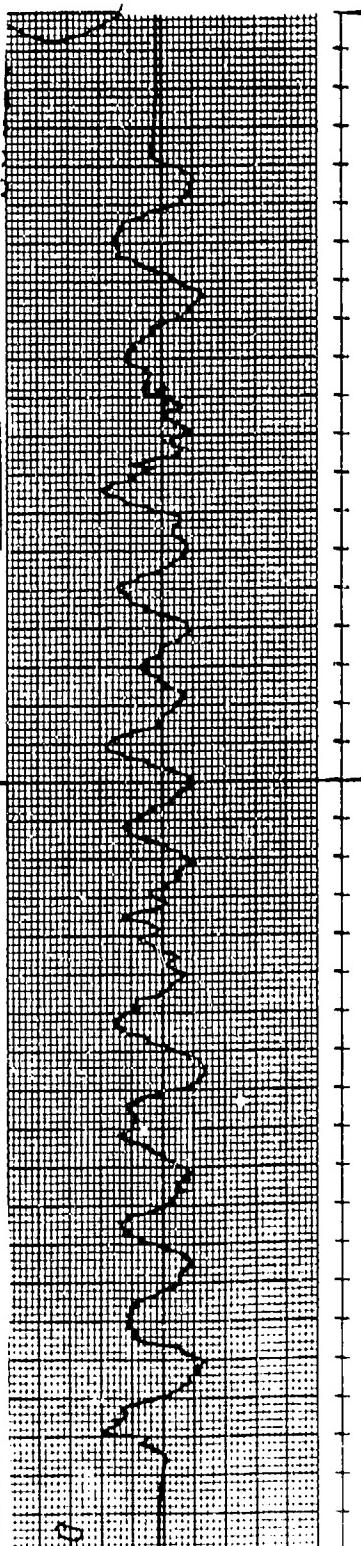
FRONT LEFT SPINDLE



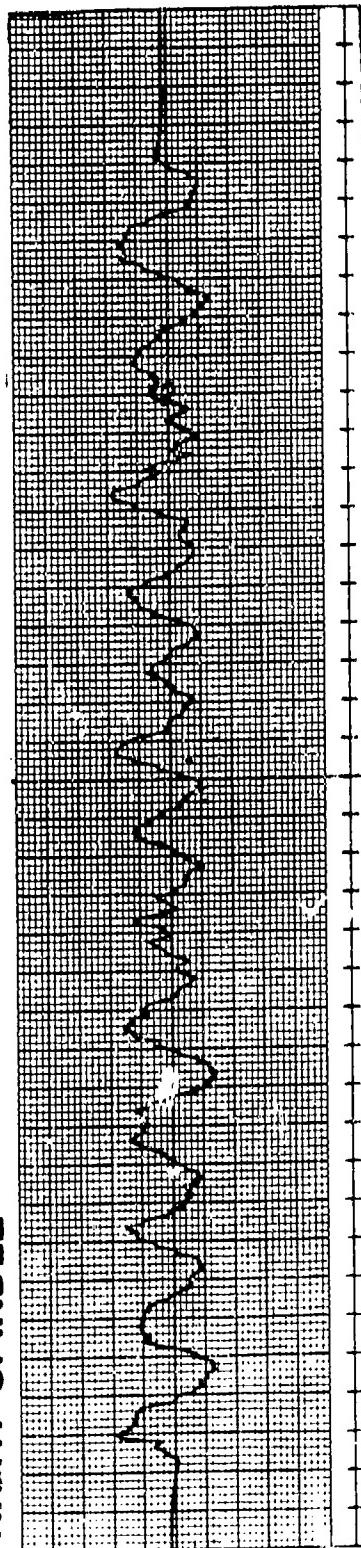
MEASURED ACTUATOR POSITION RESPONSE

FORT KNOX 8 MPH

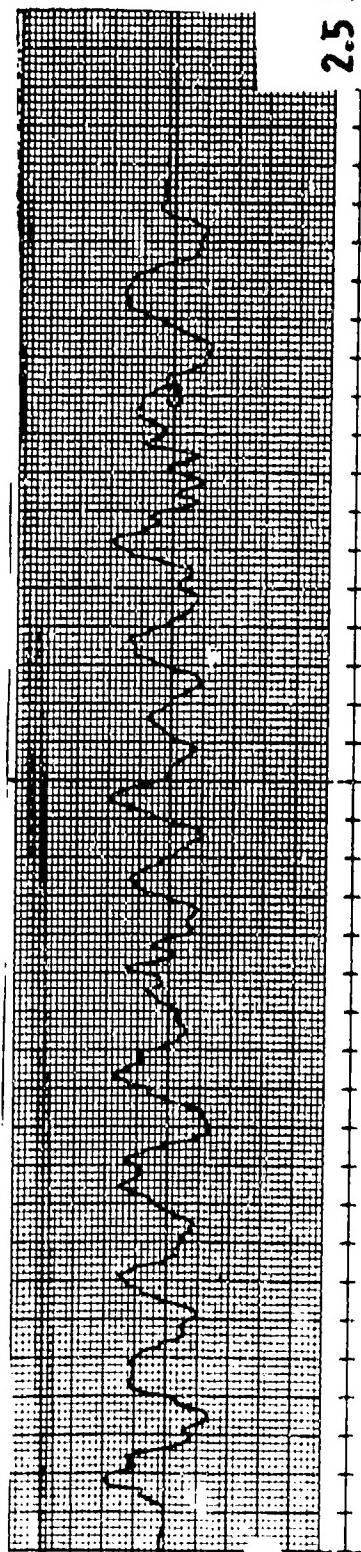
REAR RIGHT SPINDLE



MID RIGHT SPINDLE



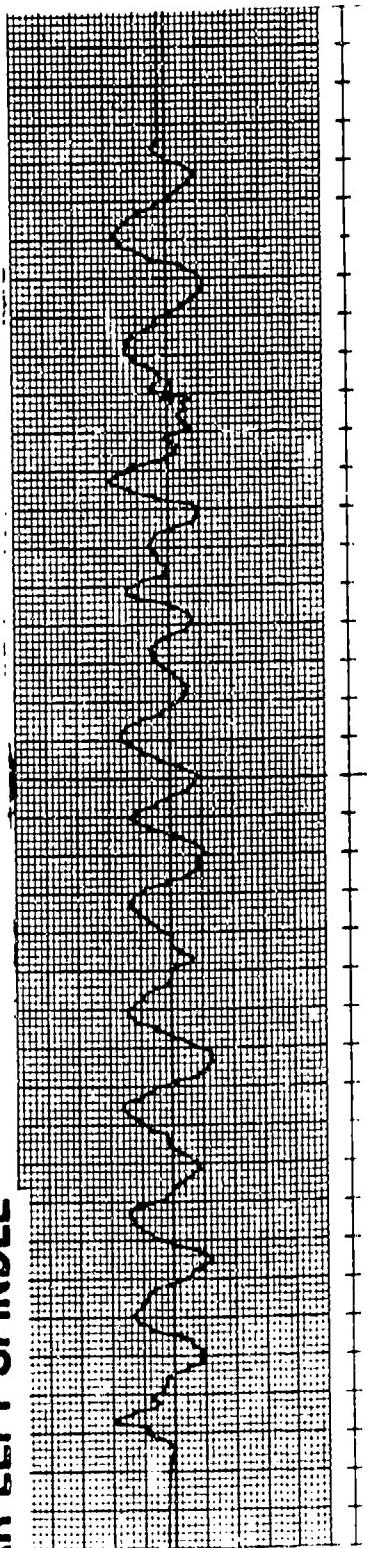
FRONT RIGHT SPINDLE



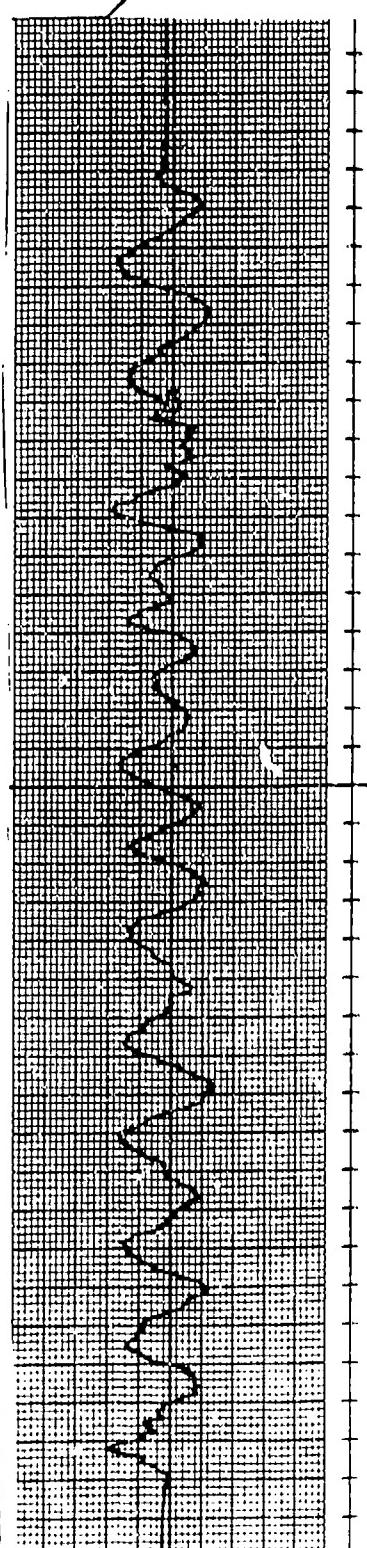
MEASURED ACTUATOR POSITION RESPONSE

FORT KNOX 8 MPH

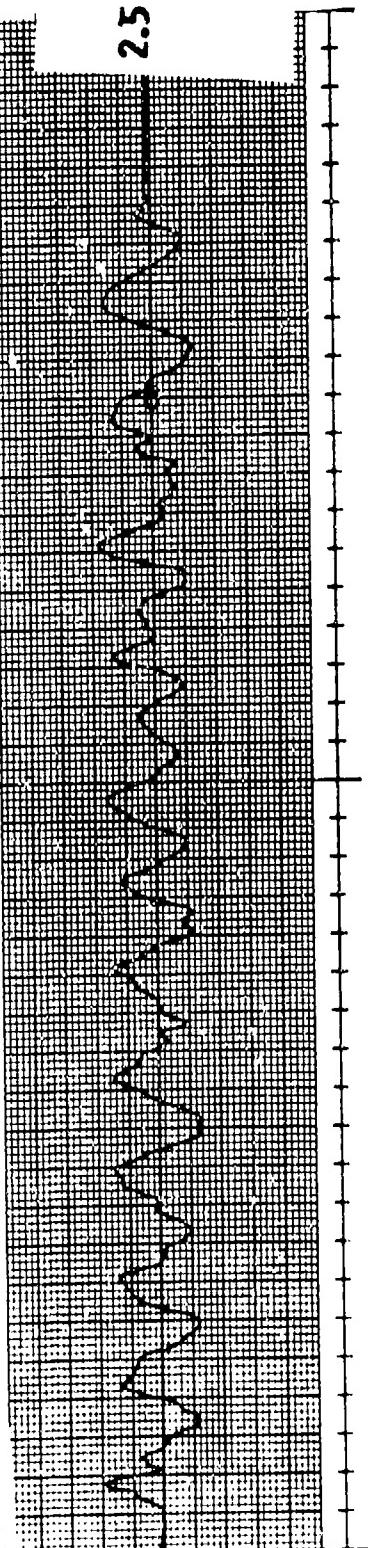
REAR LEFT SPINDLE



MID LEFT SPINDLE



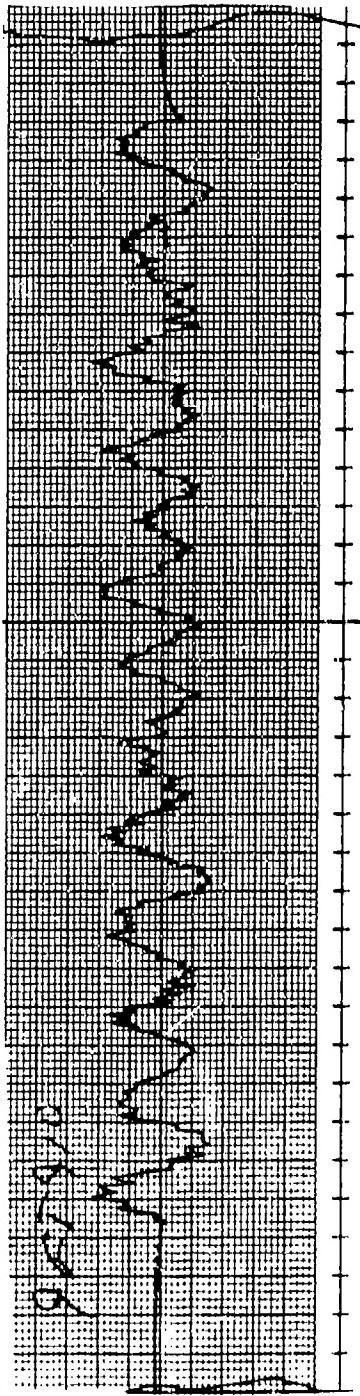
FRONT LEFT SPINDLE



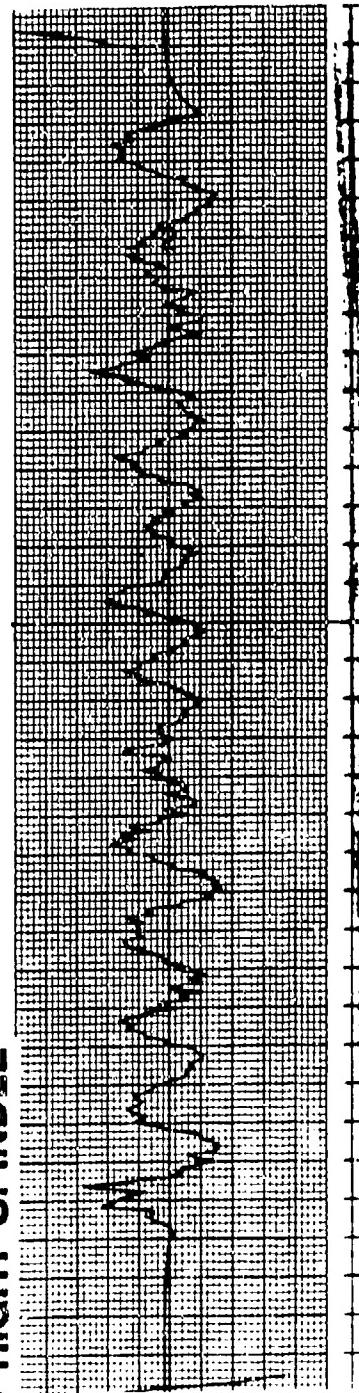
MEASURED ACTUATOR POSITION RESPONSE

FORT KNOX 9 MPH

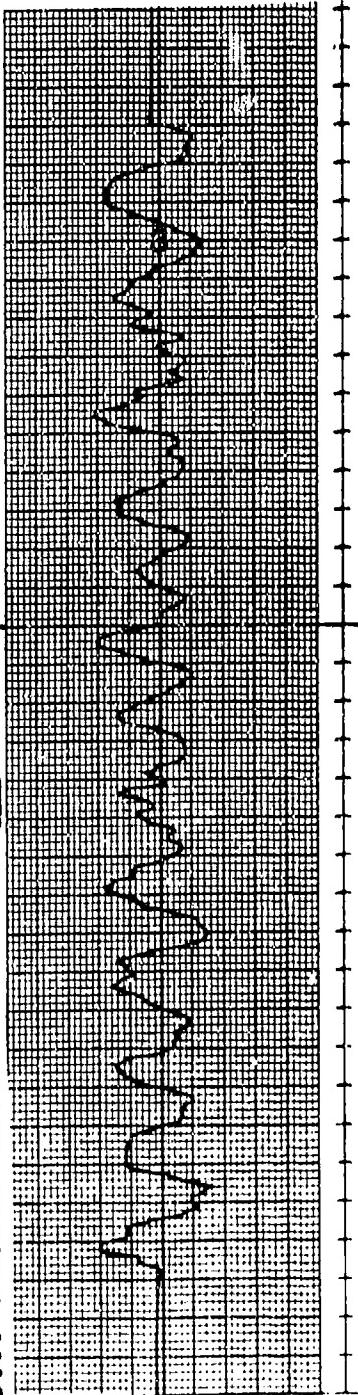
REAR RIGHT SPINDLE



MID RIGHT SPINDLE



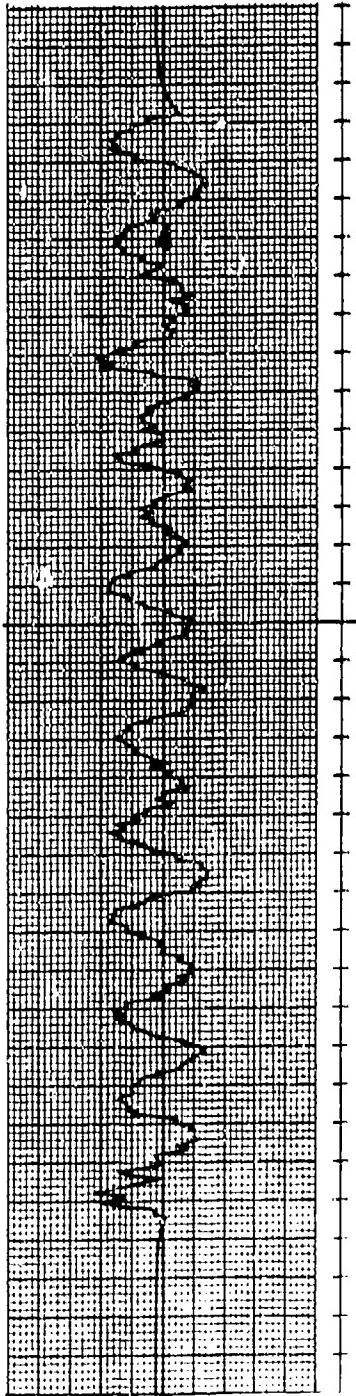
FRONT RIGHT SPINDLE



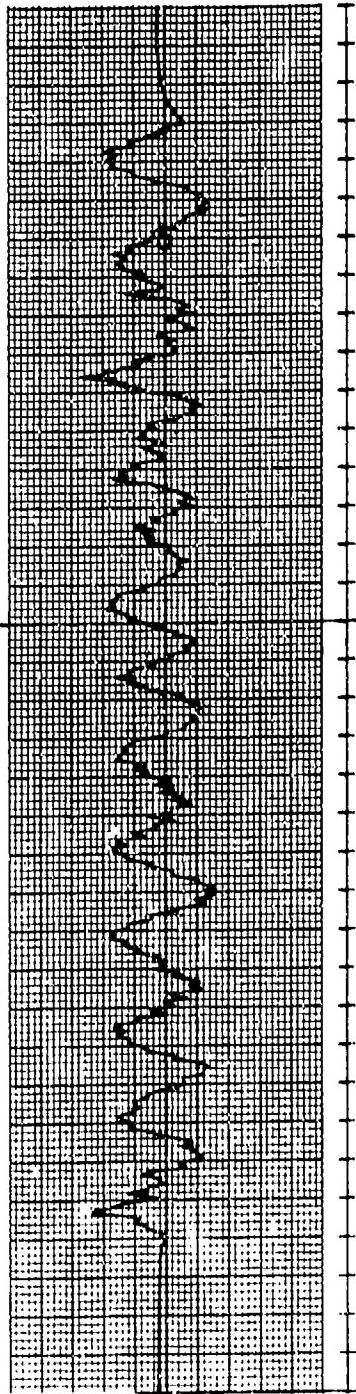
MEASURED ACTUATOR POSITION RESPONSE

FORT KNOX 9 MPH

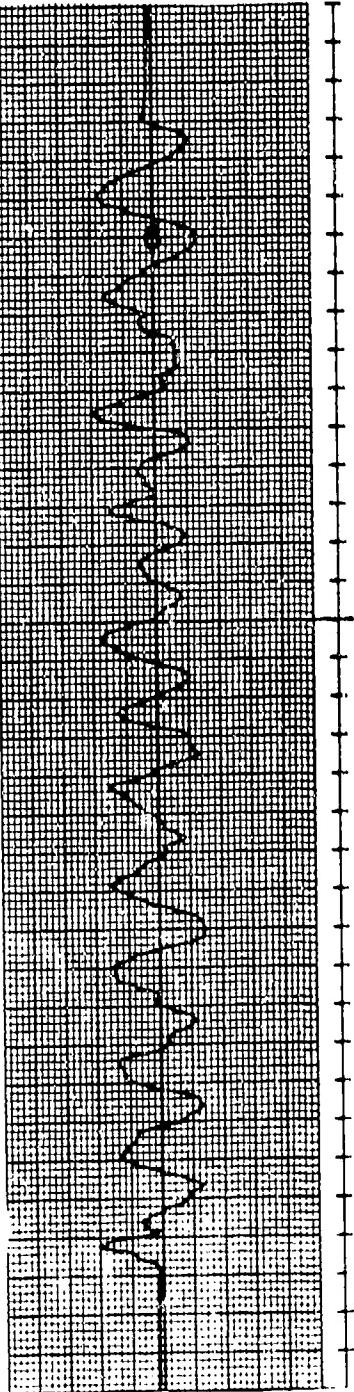
REAR LEFT SPINDLE



MID LEFT SPINDLE



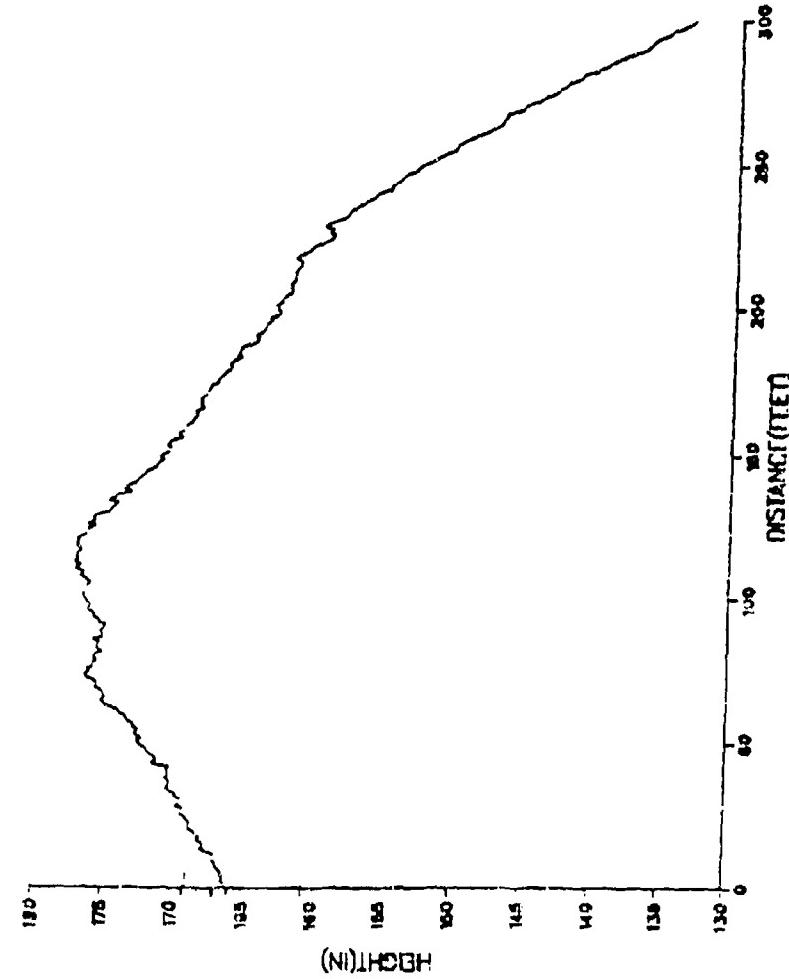
FRONT LEFT SPINDLE



APPENDIX C
TERRAIN PROFILES

COURSE PROFILE CHURCHVILLE 1

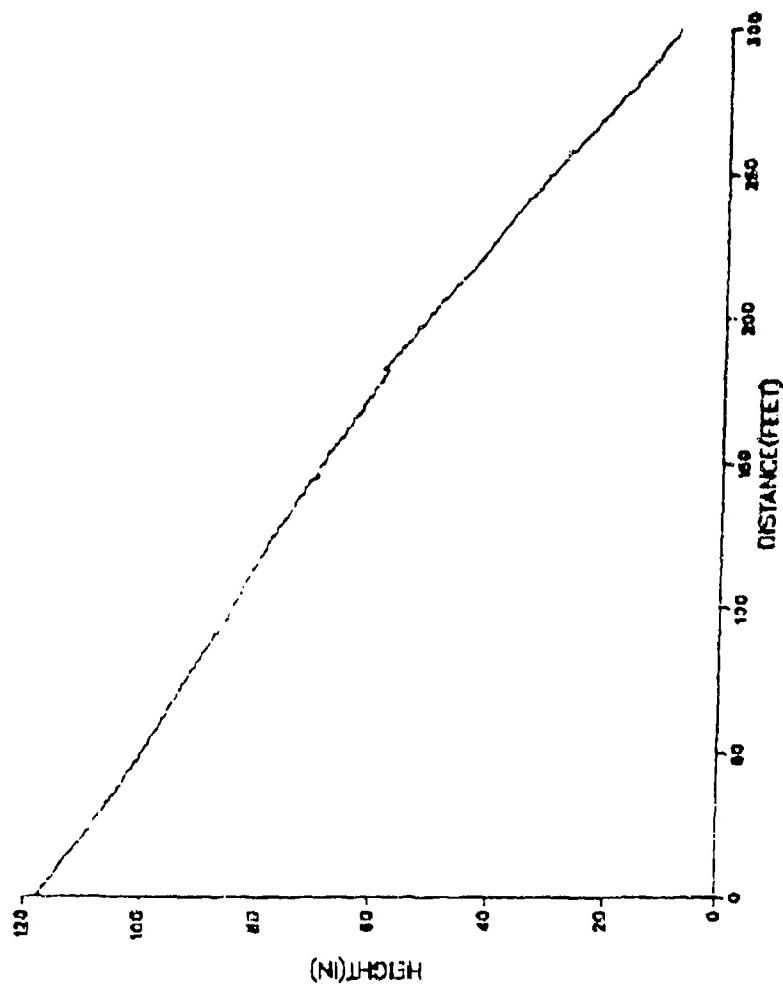
CHURCHVILLE R, 300 FEET LONG (0.36 IN. RMS) CHVI



COURSE PROFILE

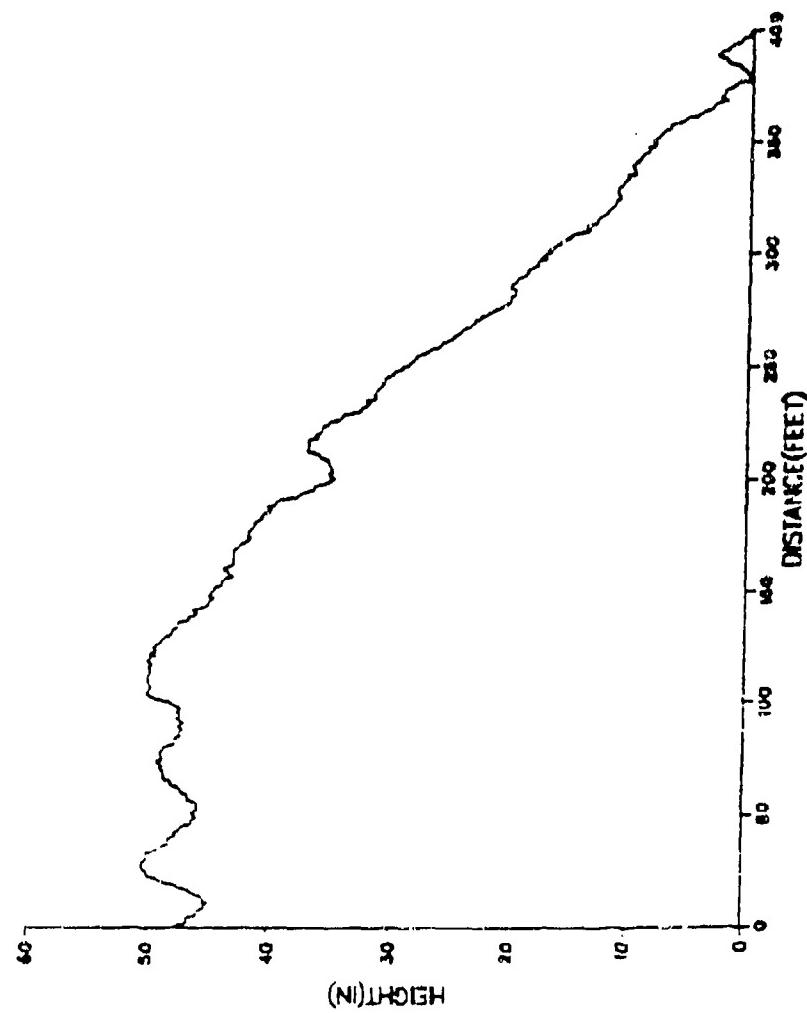
CHURCHVILLE 6

CHURCHVILLE B, 300 FEET LONG (0.24 IN. RMS) CHV6



COURSE PROFILE APG-37

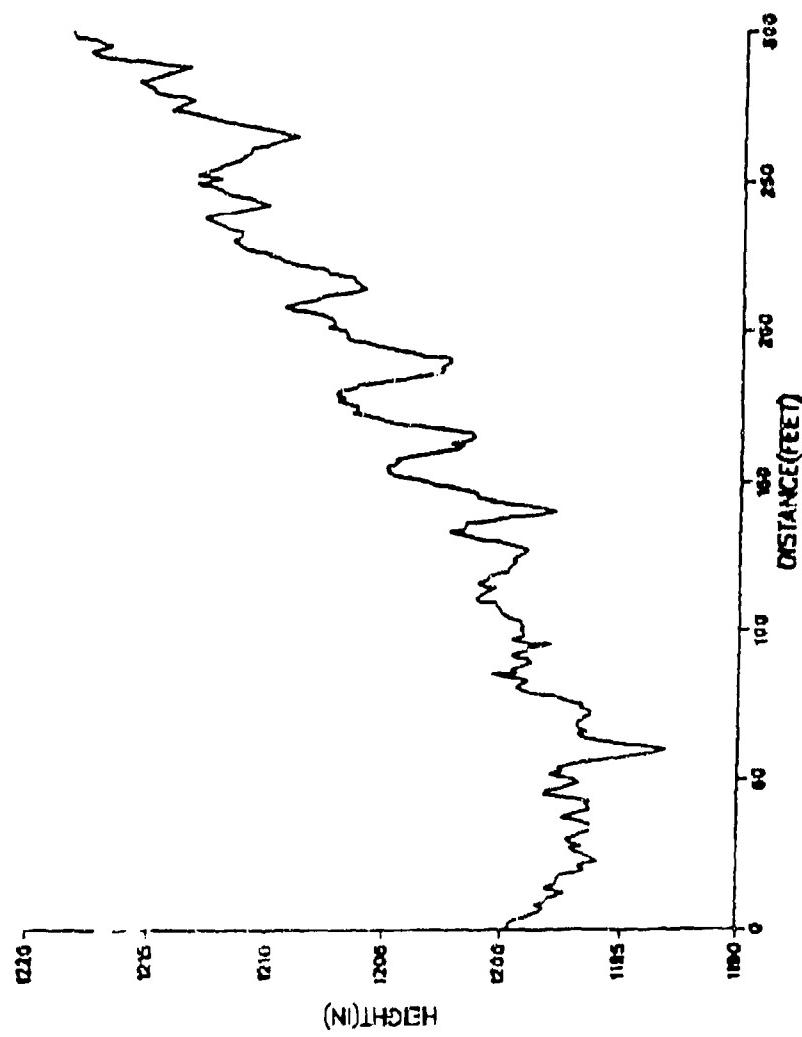
APG COURSE 37, 400 FEET LONG (0.68 IN. RMS)



COURSE PROFILE

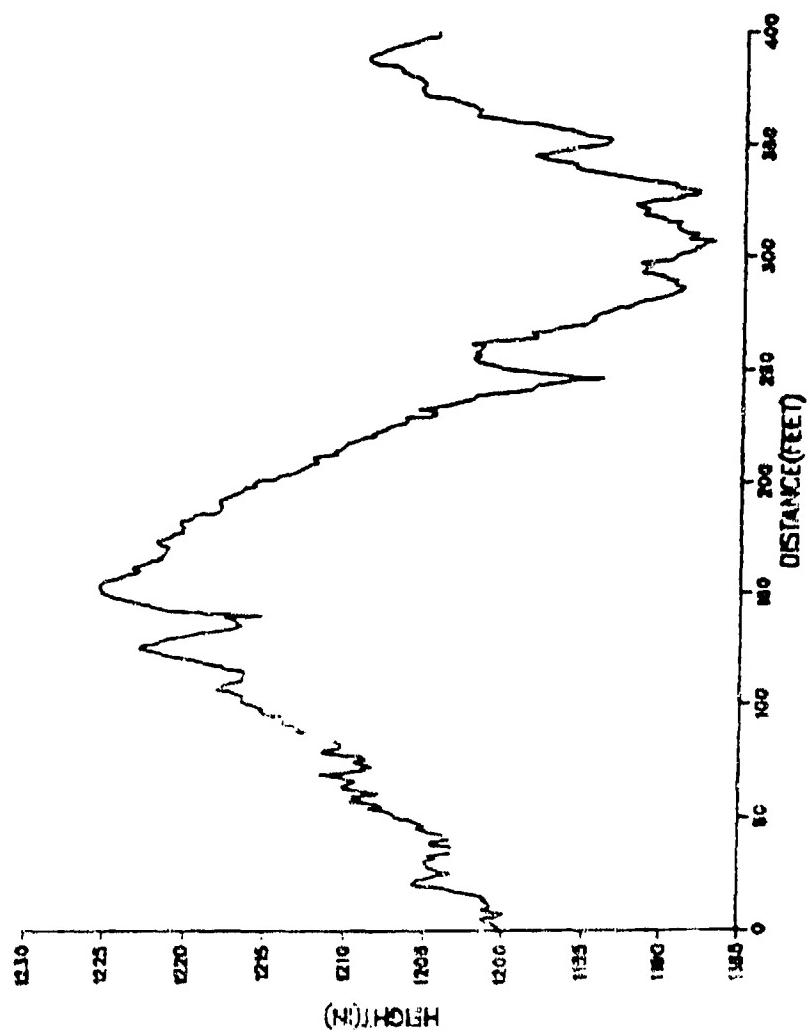
APG-9

APG COURSE 9, 300 FEET LONG (1.04 IN. RMS)



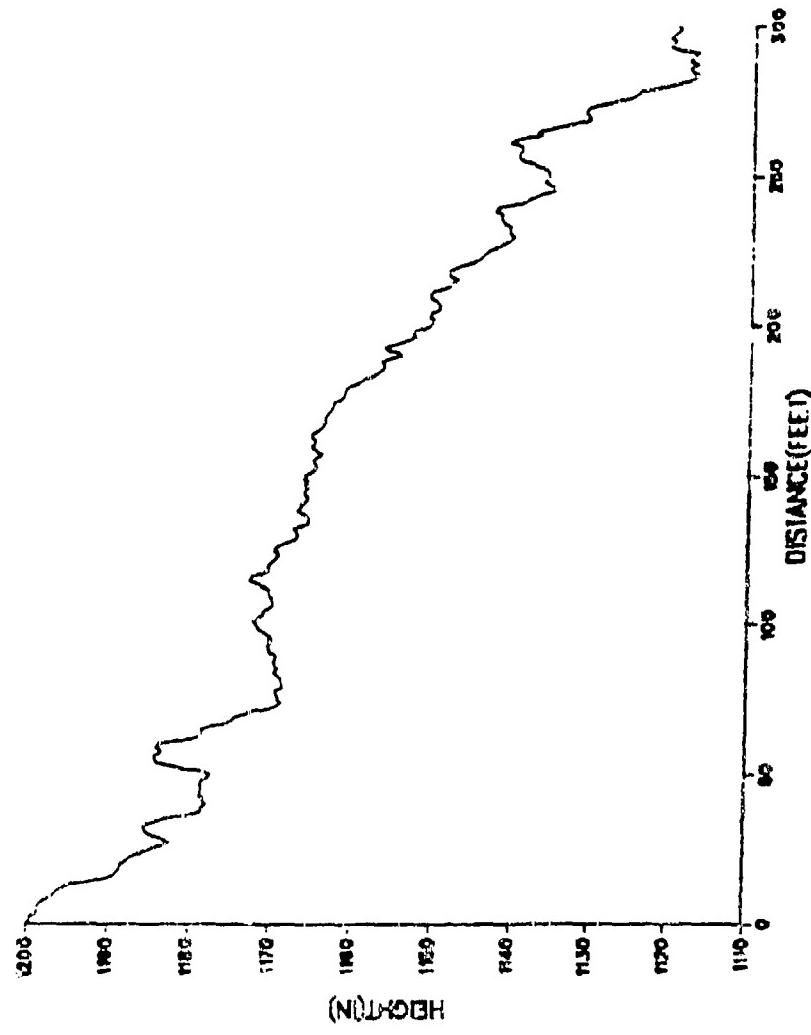
COURSE PROFILE APG-11

APG COURSE 11, 400 FEET LONG (1.32 IN. RMS)



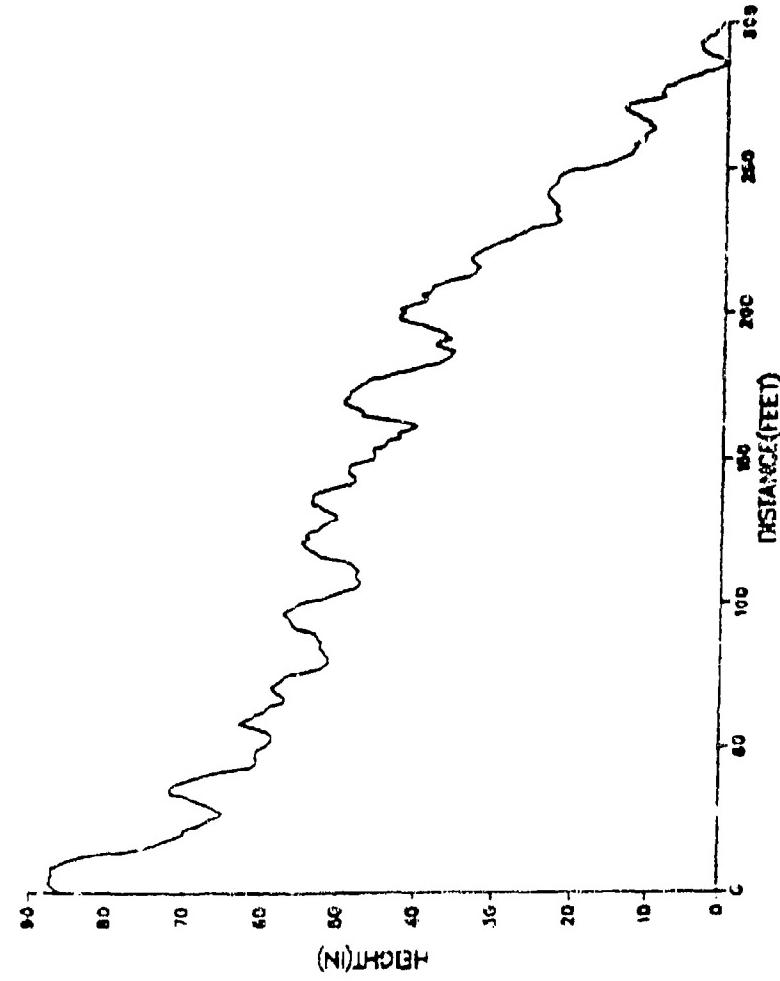
COURSE PROFILE APG-12

APG COURSE 12, 300 FEET LONG (1.70 IN. RMS)

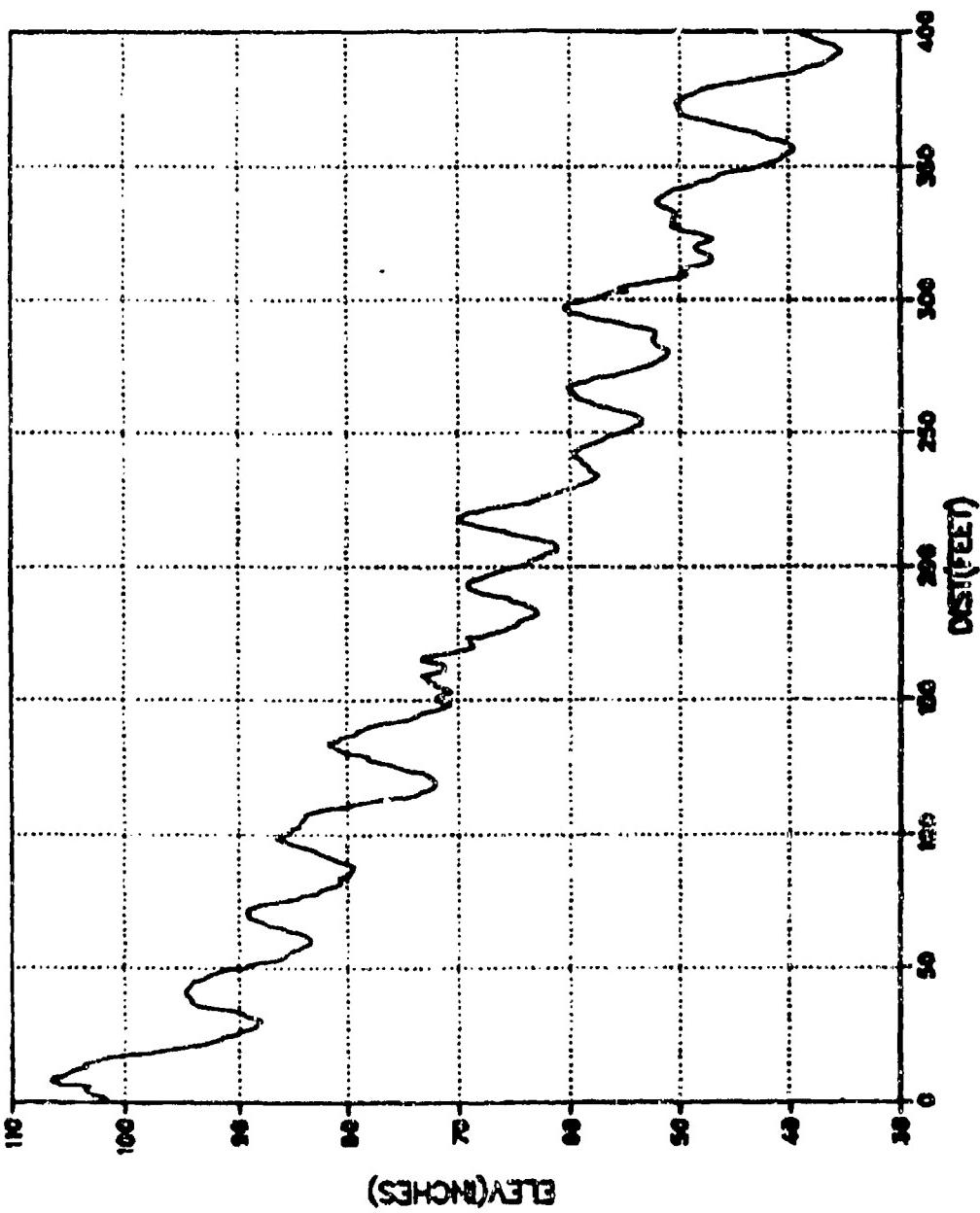


COURSE PROFILE APG-2S

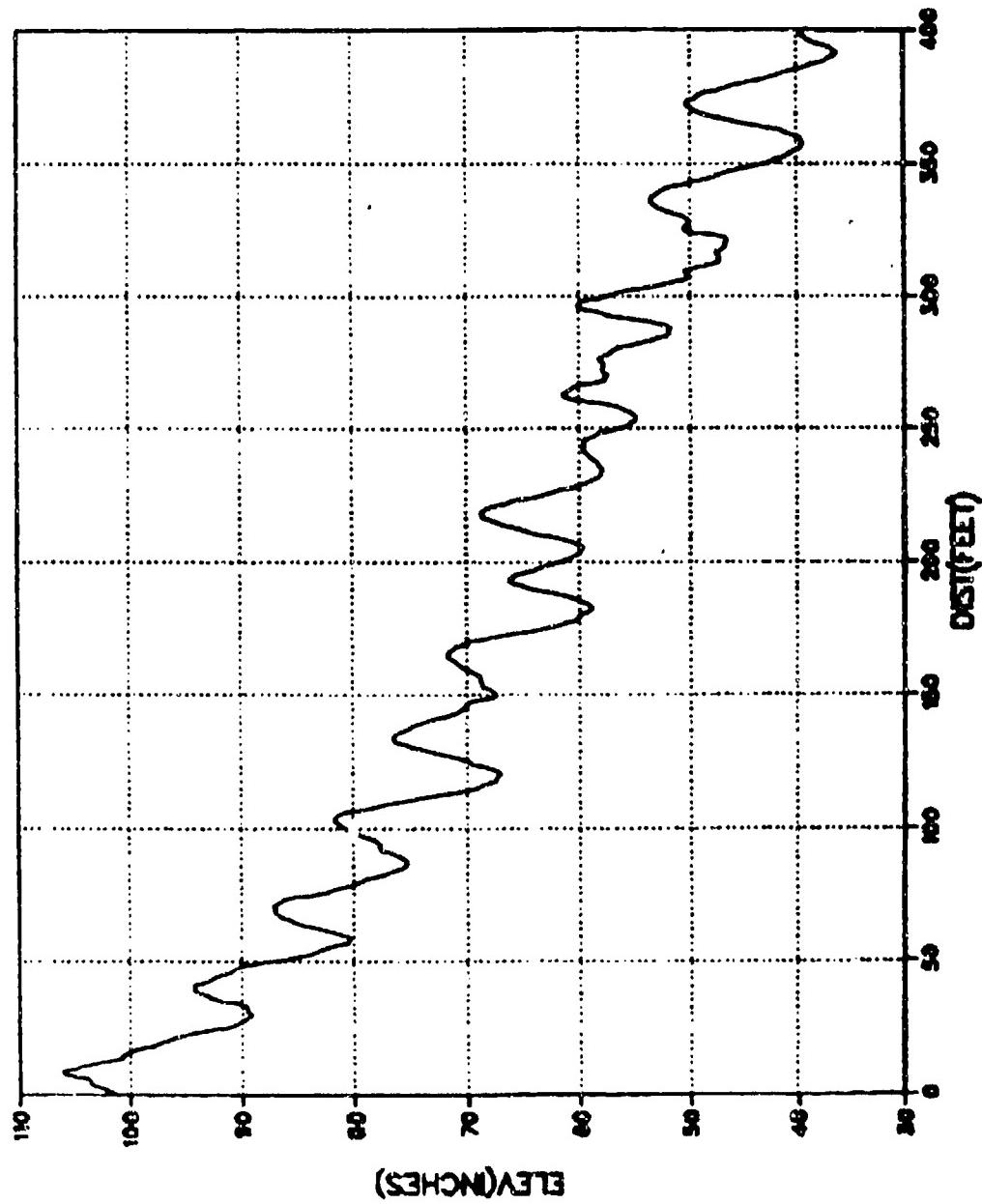
APG COURSE 29, 300 FEET LONG (217 IN. RMS)



COURSE PROFILE
FORT KNOX - RIGHT



COURSE PROFILE FORT KNOX - LEFT



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Director U.S. Army Materiel Systems Analysis Activity (AMSAA) ATTN: AMXSY-MP (Mr. Cohen) Aberdeen Proving Ground, MD 21005-5071	1